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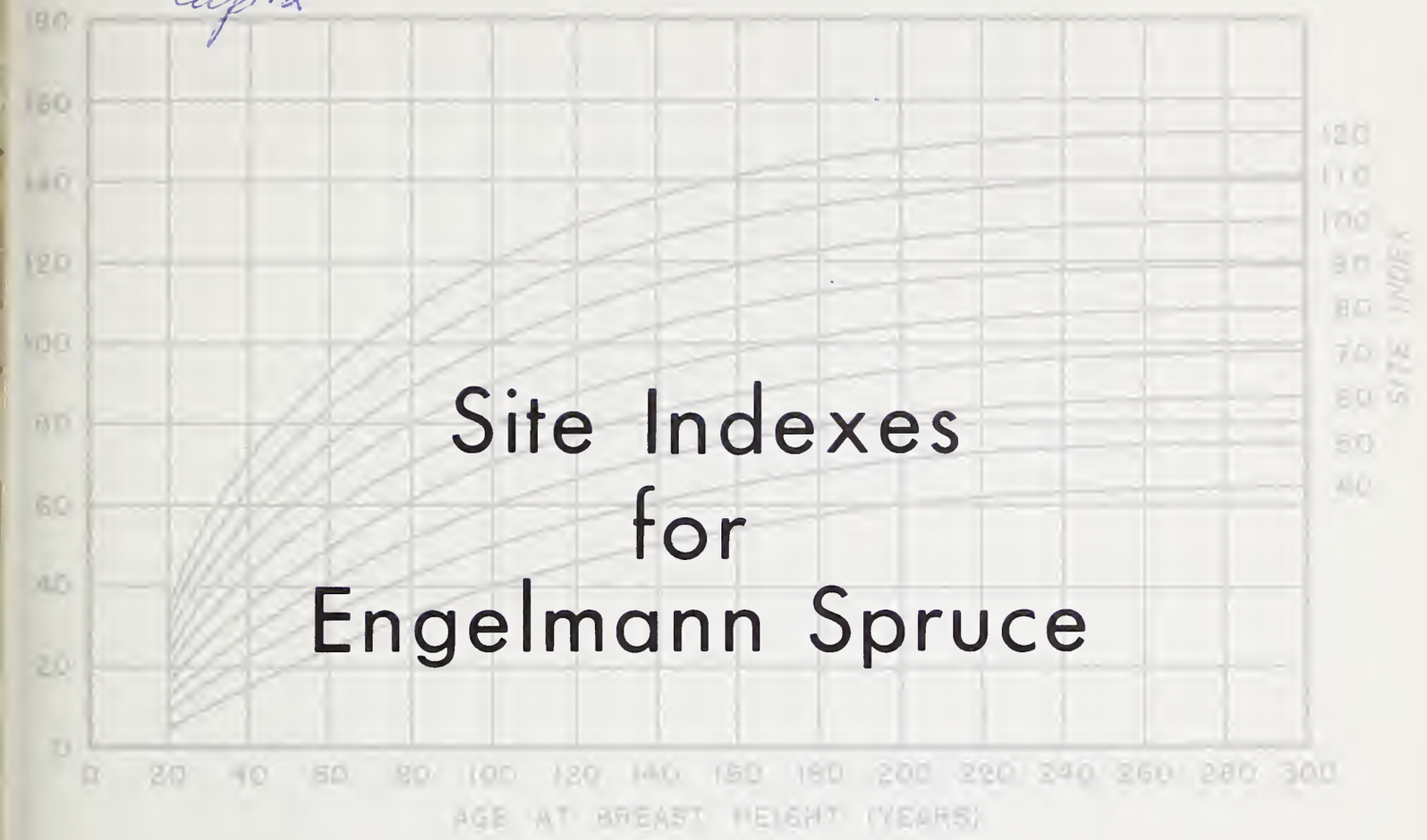

Site Indexes for Engelmann Spruce

by

Robert R. Alexander

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Site Indexes for Engelmann Spruce in the Central Rocky Mountains

by

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Site Indexes for Engelmann Spruce in the Central Rocky Mountains

Robert R. Alexander

Productive capacities of different forest environments for any species are commonly expressed as site indexes. The only site index curves previously developed for Engelmann spruce (Picea engelmannii Parry)-subalpine fir (Abies lasiocarpa (Hook.) Nutt.) forests in Colorado and Wyoming apply only to trees left after partial cutting (Hornibrook 1942).[2] This paper presents the basic height-age curves needed to classify uncut spruce stands according to site quality.

Specifications For Engelmann Spruce Site Curves

The height-age curves were developed by the anamorphic curve technique developed by Bruce (1926) and others, and described by Bruce and Schumacher (1950). Since Engelmann spruce is the dominant component of the type, measurements were confined to spruce.

The dominant height of spruce appears to be independent of stand density over a wide range of stocking. Therefore, the family of site curves developed for spruce is simply the expression of the relationship between height growth and the independent variables of site quality and age. Other considerations were:

Age at breast height (4.5 feet) rather than total age.—The use of breast height age taken directly from increment cores is more convenient, and eliminates the need for adding arbitrary corrections to convert breast height age to total age. Furthermore, at breast height, tree age is determined after the initial period of establishment and adjustment. Free-growing spruce may require from 20 to 40 years to reach breast height, and suppressed trees may require as long as 100 years.

Restriction of site trees to dominants.—Dominant trees represent the most stable component of the stand, and are therefore the most reliable indicators of site productivity. The variation in height growth of dominants alone is less than that of dominants and codominants combined. By restricting the choice of site trees to dominants, fewer measurements are needed for a given degree of accuracy (Ker 1952, Staebler 1948).

Selection of six site trees at each location.—Six trees were chosen for site measurements because Brickell (1966), Johnson and Carmean (1953), Ker (1952), and others have shown that satisfactory standard errors in site index determination can be obtained from measurements of six site trees.

Index age at 100 years.—A breast height age of 100 years was selected because it closely approximates the anticipated rotation age for managed stands of spruce in the central Rocky Mountains.

Source Of Data

To determine height-age relationships, data were collected in 1965 and 1966 from 350 randomly selected stands. Because of the possibility that the shape of the height-age curves might be influenced by soils and climate, the spruce-fir type in the central Rocky Mountains was divided into the following three subregions on the basis of general soil, topographic, and climatic differences:

[2] *Names and dates in parentheses refer to Literature Cited, p. 7.*

Subregion	Plots (No.)
Mountain spruce.—Includes all the spruce forests on the (1) Arapaho, Bighorn, Medicine Bow, Pike, Roosevelt, San Isabel, and Shoshone National Forests; (2) Routt National Forest except the Yampa District; (3) mountainous portion of the White River and Gunnison National Forests except the Cebolla District of the Gunnison; and (4) the Saguache District of the Rio Grande National Forest on the west side of the Sangre de Cristo Mountains.	127
Mesa spruce.—Includes all the spruce forests on the plateaus of the (1) White River, Gunnison, Uncompahgre, and Grand Mesa National Forests; and (2) Yampa District of the Routt National Forest.	107
Southwestern Colorado spruce.—Includes all the spruce on the (1) San Juan National Forest; (2) Rio Grande National Forest except that part of the Saguache District in the mountain spruce; (3) mountainous portion of the Uncompahgre National Forest; and (4) Cebolla District of the Gunnison National Forest.	116

In each stand sampled, six trees were selected from the dominants in that stand for site determination. Sampling was confined to stands that were (1) even-aged, (2) at least 4.5 feet tall, (3) free of fire or logging throughout their lives, and (4) typed as spruce-fir. In addition to being dominants, site trees were also required to be (1) on the same apparent site at any location—site was considered the same if all trees were growing on similar topography, slope, aspect, and soils, (2) not more than 300 years old at breast height, (3) straight and sound enough for ring counts, and (4) free of defect or past suppression that would affect height growth.

Measurements taken from each site tree were diameter at breast height (d.b.h.), total height, age at breast height, and preliminary site index. D.b.h. was measured to nearest 1/10 inch with a diameter tape. Heights were measured to the nearest foot with an Abney level and chain. Age was determined from increment cores, which were accepted only if they reached the pith. Preliminary site index was assigned each plot on the basis of average age and height from Brickell's (1966) site index curves adjusted to reference age 100 years.

The dominant stands selected for sampling ranged in average age from 14 to 304 years old at breast height, and in average height from 10 to 132 feet. The distribution of stands sampled by height and age are shown in figure 1; site

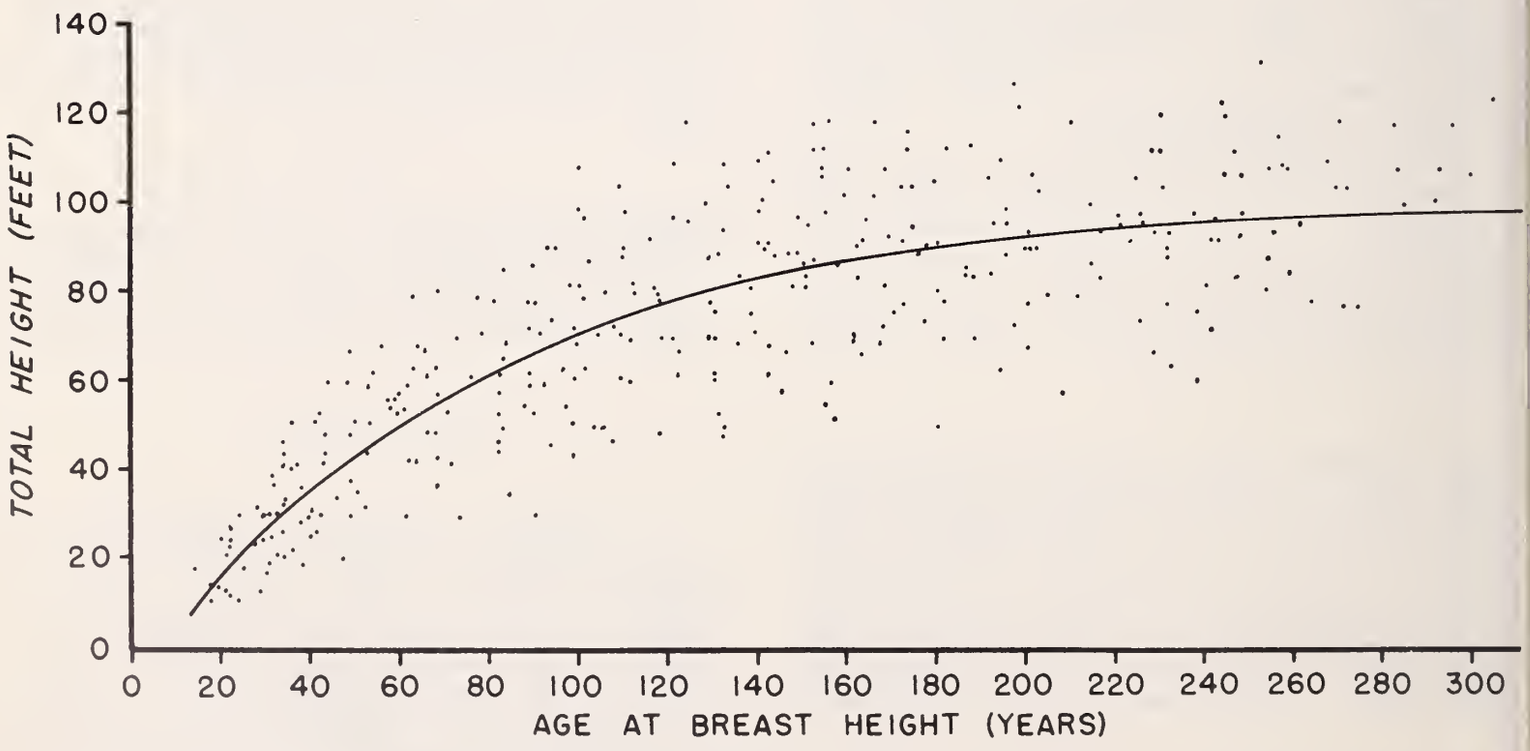

Figure 1.--Regional guide curve in relation to the distribution of height-age data from all stands.

and age in figure 2. The site indexes in figure 2 are based on the curves developed in this study.

Analysis Of Data

Preparing the Height-Age Data for Use

The average height-age data from each stand were sorted into 20-year age classes, and the average age and height were determined for each class. The average height of each class was then plotted over its corresponding average age, and a guide curve fitted to the resulting distribution. The average height at age 100 years for this regional guide curve was 71 feet. This procedure was then repeated with the height-age data from each subregion. The average height at age 100 years for the guide curves was 64, 71, and 78 feet for the mountain, southwestern, and mesa subregions, respectively.

Comparing Guide Curves

To test for any substantial differences between the shape of the regional guide curve and those for each subregion, the guide curves for each subregion were adjusted to the same height at age 100 years (71 feet) as the regional guide curve. The differences in height between the regional guide curve and the guide curves for each subregion were then determined for each decade of age from 20 to 300 years. Mean differences in height, estimated by the regional guide curve and the guide curves for each subregion, were:

	Age interval (years)		
	20-90	110-200	210-300
		—(Feet)—	
Mountain	-0.55	1.85	4.46
Southwestern	- .31	1.15	4.15
Mesa	1.42	-3.98	-3.14

The guide curve for the mountain and southwestern subregions closely approximated the regional guide curve up to age 200 years. From ages 200 to 300 years, the guide curves for both subregions estimated height about 4 feet higher than the regional guide curve.

The guide curve for the mesa subregion also closely approximated the regional guide curve up to age 100 years. Thereafter, the mesa guide curve estimated height from 3 to 5 feet lower than the regional guide curve.

The deviations in height between the regional guide curve and the guide curves for each subregion in the older ages were due to unavoidable sampling bias that caused some distortion in the

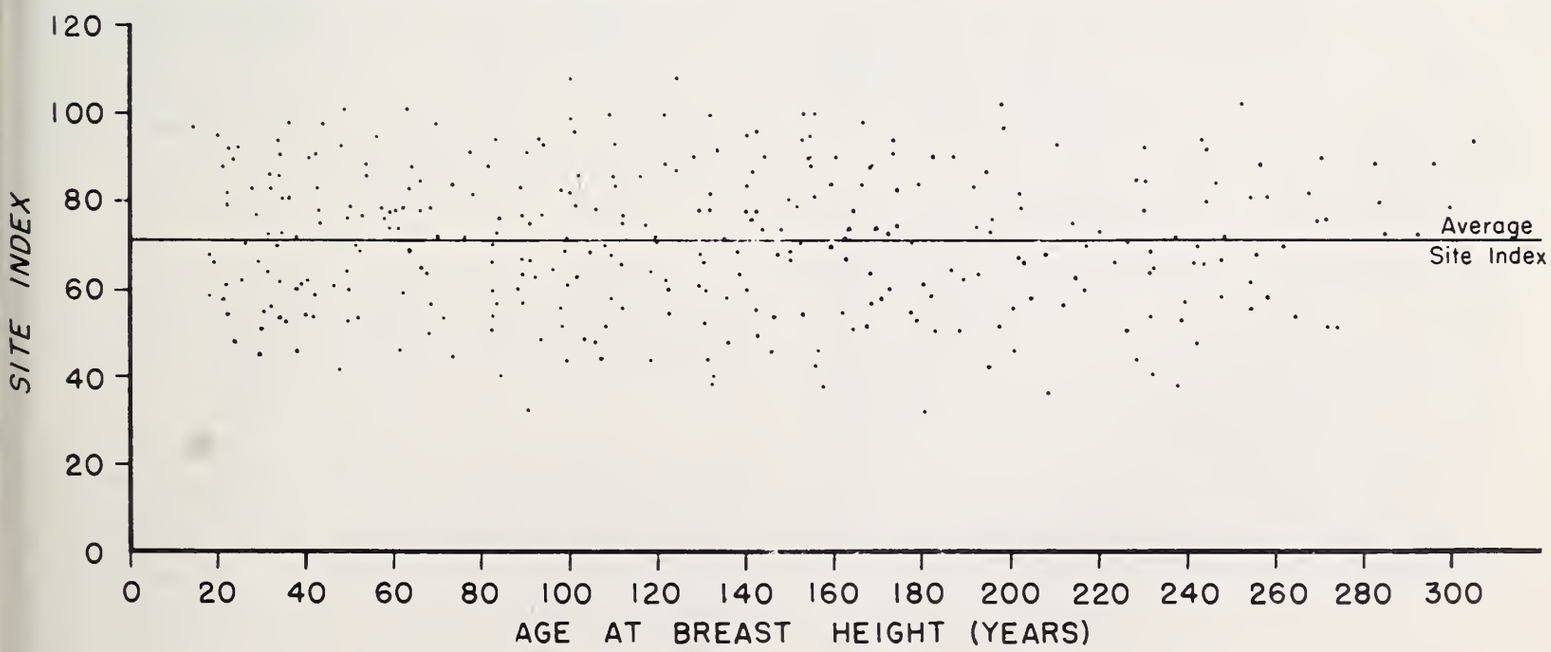

Figure 2.--The relationship of site quality to stand age.

guide curves for each subregion in the older age classes. In the mountain and southwestern subregions, there were fewer stands older than 200 years, and most of those were located on above-average sites because stands at those advanced ages had begun to break up on poorer sites. That bias resulted in an upward distortion of both guide curves beyond age 200 years. In the mesa subregion, more stands older than 100 years were located on below-average sites because most of the good sites were located on the White River Plateau, and few stands older than 100 years survived the 1939-52 spruce beetle outbreak. That bias resulted in a downwarping of the mesa subregion guide curve in the older age classes.

The differences in curve shapes between the regional guide curve and the guide curve for each subregion do not warrant the development of a separate set of site index curves for each subregion. The differences in curves are too small to be of any practical significance in the range of ages—20 to 150 years—likely to be considered for managed stands. Furthermore, combining all the data and fitting one curve to the resulting distribution actually reduced sampling bias because a better sample was obtained across the range of site indexes of all ages (fig. 1).

Testing for Differences in Curve Shape Between Sites

Before preparing the family of site index curves, it was necessary to test the assumption that the true curves of dominant height on age for different sites were strictly proportional to the shape of the guiding curve.

The coefficient of variation was determined for each 20-year age class, and plotted over the corresponding average age for the class (Chapman and Meyer 1949). The assumption of proportional shape was not supported. The plotted points fell in a curved line. A curve was fitted to those points, and the coefficient of variation for each decadal age from 20 to 300 years was read from the curve.

The family of height-age curves for site indexes 40 to 120 was then prepared by the following procedure:

1. For each 10-foot site index class, an adjustment factor was computed as follows:

$$A = \frac{S - G}{H \times C}$$

where:

A = adjustment factor at any age
S = site index height
G = guide curve height at age 100 years
H = guide curve height
C = coefficient of variation at age 100 years

2. This adjustment factor was then used to determine the distance in percent from the guide curve at decadal ages 20 to 90 and 110 to 300 years for each 10-foot site index class as follows:

$$D = A \times C$$

where:

D = difference in percent from guide curve at decadal ages 20-90 and 110-300 years
A = adjustment factor
C = coefficient of variation at corresponding decadal age

3. The percentages for each 10-foot site index class for decadal ages 20 to 90 and 110 to 300 years were then converted to feet by multiplying by the guide curve height at the corresponding decadal age.

4. The differences between the guide curve height and the heights for each 10-foot site index class for decadal ages 20 to 90 and 110 to 300 years were then plotted, and the points connected with smooth curves.

Testing Dependence of Site Quality on Stand Age

To explore the possibility of a correlation between site quality and stand age, site index was determined for each of the 350 stands sampled and plotted over the corresponding average stand age (fig. 2). No relationship was apparent; therefore, the assumption that site quality is independent of stand age appears valid.

Results

The site curves developed in this study are shown in figure 3. Table 1 shows the expected height of trees in the dominant stand at breast height ages 20 to 300 years for site indexes 40 to 120.

Field Application

To determine site index for any spruce stand, average dominant stand height and age must be obtained from measurements of total height and breast height age of six or more of the taller dominants in a stand where all trees are growing on the same apparent site. Height readings should be taken from a measured base line laid out on the contour if possible; otherwise, corrected slope distance should be used. Increment cores should be extracted to the pith from each tree for age determination.

In addition to being dominants, trees selected for measurement should meet the following specifications:

1. Even-aged—not more than a 20-year spread in the age of the dominant stand.
2. At least 20 years old at breast height—preferably 50 years old or older, because of the variability in height growth of trees on the same site at ages 20 to 50 years.
3. Show no visible evidence of crown damage such as broken or forked tops, disease, or excessive sweep or crook.
4. Increment core shows a normal pattern of ring widths from pith to cambium, indicating no evidence of past injuries nor prolonged suppression.

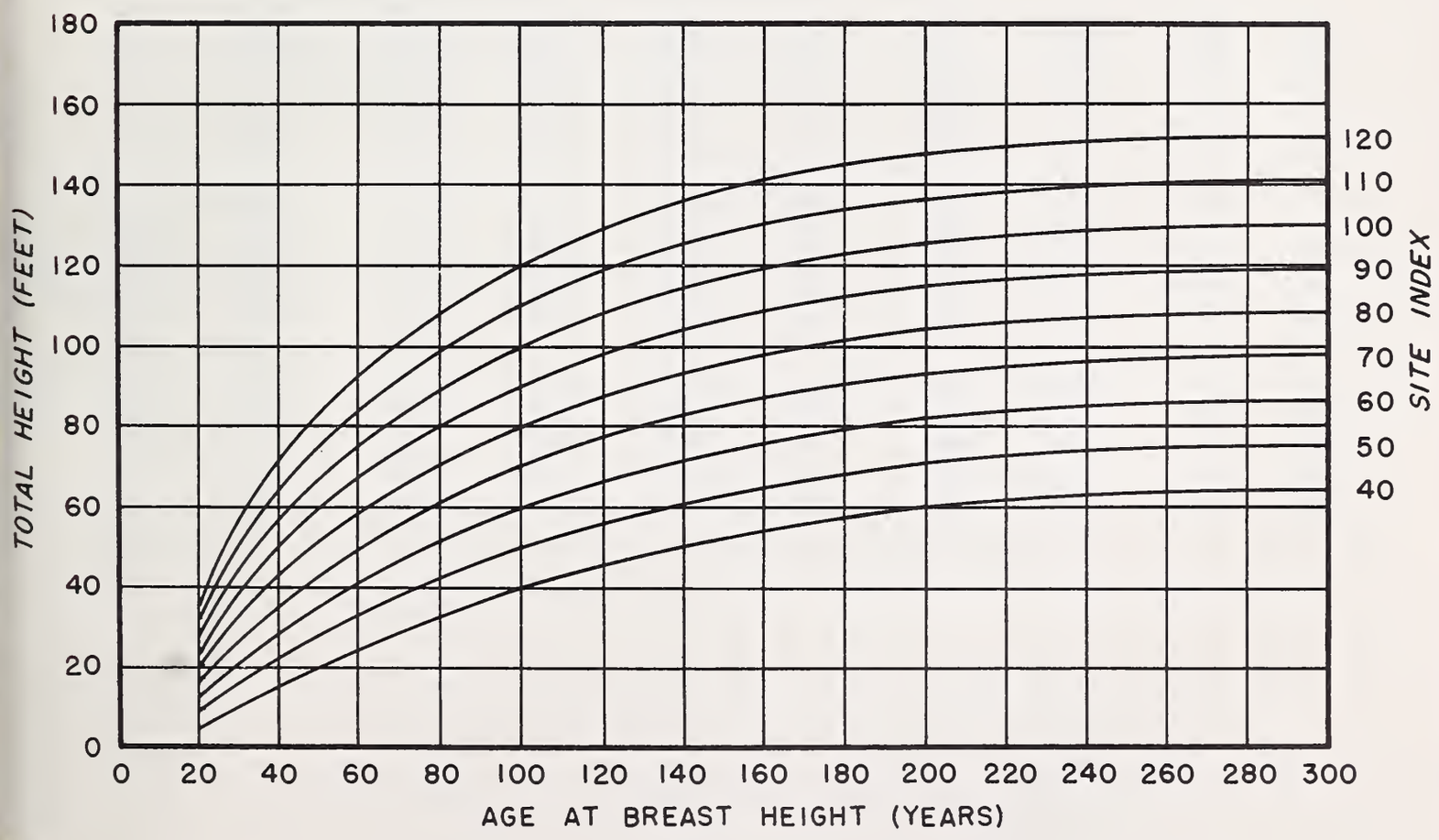

Figure 3.--Site index curves for Engelmann spruce in the central Rocky Mountains. Base age: 100 years, breast height.

Table 1.--Expected height of Engelmann spruce trees in the dominant stand for site indexes 40 to 120, by decadal ages 20 to 300 years breast height

Breast height age (Years)	Site index class								
	40	50	60	70	80	90	100	110	120
	Height in feet								
20	6	9	13	16	20	23	27	30	34
30	11	16	22	27	33	39	44	50	55
40	15	22	29	36	43	50	57	64	71
50	20	28	36	44	52	59	67	75	83
60	24	33	42	50	59	67	76	84	93
70	29	38	47	56	65	74	83	92	101
80	33	42	52	61	70	80	89	98	108
90	37	46	56	66	75	85	95	104	114
100	40	50	60	70	80	90	100	110	120
110	43	53	64	74	84	94	105	115	125
120	46	56	67	77	88	98	109	119	130
130	48	59	70	80	91	101	112	123	133
140	51	61	72	83	94	104	115	126	136
150	53	64	74	85	96	107	118	129	139
160	55	66	76	87	98	109	120	131	142
170	56	67	78	89	100	111	122	133	144
180	58	69	80	90	101	112	123	134	145
190	59	70	81	92	103	114	125	135	146
200	60	71	82	93	104	115	126	136	147
210	61	72	83	94	105	116	127	137	148
220	62	73	84	95	106	117	127	138	149
230	63	74	85	95	106	117	128	139	150
240	63	74	85	96	107	118	129	140	150
250	64	75	86	96	107	118	129	140	151
260	64	75	86	97	108	118	129	140	151
270	64	75	86	97	108	119	130	141	152
280	64	75	86	97	108	119	130	141	152
290	64	75	86	97	108	119	130	141	152
300	64	75	86	97	108	119	130	141	152

Literature Cited

Brickell, James E.
1966. Site index curves for Engelmann spruce in the northern and central Rocky Mountains.* U.S. Forest Serv. Res. Note INT-42, 8 p., illus. Intermountain Forest and Range Exp. Sta., Ogden, Utah.

Bruce, D. B.
1926. A method of preparing timber yield tables. J. Agr. Res. 32: 543-557, illus.

_____ and Schumacher, F. X.
1950. Forest mensuration. 483 p., illus. New York: McGraw-Hill Publ. Co.

Chapman, Herman H., and Meyer, Walter H.
1949. Forest mensuration. 522 p., illus. New York: McGraw-Hill Publ. Co.

Hornibrook, E. M.
1942. Yield of cutover stands of Engelmann spruce. J. Forest. 40: 778-781.

Johnson, Floyd A., and Carmean, Willard H.
1953. Sampling error in estimation of site index. J. Forest. 51: 26-27.

Ker, J. W.
1952. An evaluation of several methods of estimating site index in immature stands. Forest. Chron. 28: 63-74.

Staebler, George R.
1948. Use of dominant tree heights in determining site index of Douglas-fir.* U.S. Forest Serv. Pacific Northwest Forest and Range Exp. Sta. Res. Note 44, 3 p. Portland, Ore.

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Figures and tables are presented for estimating site indexes for Engelmann spruce from data collected in Colorado and Wyoming. Site index is expressed as the average height of dominant spruce trees in spruce-fir stands at breast height age 100 years.

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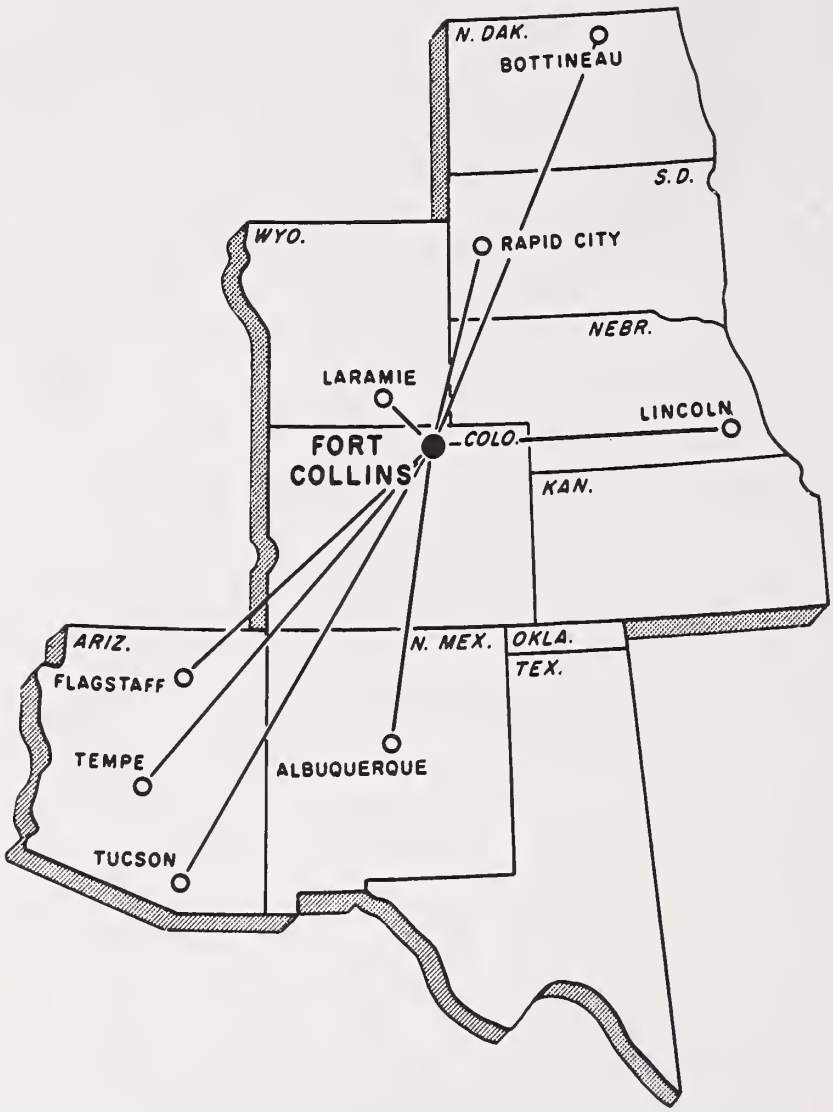
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